KESTREL SEISMOGEODETIC: A UNIQUE MONITORING SYSTEM

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by Christian Breuer

Victoria Dam, Sri Lanka

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Kestrel Seismogeodetic: A Unique Monitoring System

With any built structure, there is a responsibility for safety. A construction plan will have safety measures and practices built in to keep workers and buildings around construction sites safe, but safety goes beyond the final phase of construction. Monitoring the movement of structures after they have been built requires equipment that can provide real-time, highly accurate data and alerts. And, for structures that may experience regular vibrations - from automotive traffic, seismic activity or even the structure itself, data is required to provide the best look at the moment-to-moment integrity of the structure.

Since 2000, there have been more than 100 bridge failures (Wikipedia) and 39 major dam failures (Wikipedia) around the world, some causing immense damage and loss of life. According to the Federal Emergency Management Agency (FEMA), there are nearly 100,000 dams in the United States alone, of which approximately 30 percent pose a “high” or “significant” risk to life and property if a failure were to occur (FEMA). Structural monitoring systems helps to mitigate the risk of structural failures and reduce the cost of repair, maintenance and

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inspection by providing insight into the status of critical infrastructure in real-time.

An Unparalleled Solution

When monitoring the movements of a structure, there are many solutions available, often combining many types sensors from different manufacturers. One solution is the Trimble® Kestrel™ seismogeodetic system. Pairing high-quality Global Navigation Satellite System (GNSS) positions with seismic data for monitoring the movement of bridges, dams, towers and other civil structures, Kestrel is an innovative solution for structural engineers.

Unmatched in the industry, Kestrel combines and processes GNSS and acceleration data using advanced processing techniques to generate 200 Hz displacement data in real-time, providing structural engineers and scientists the detailed information required for dynamic analysis. For general structural health monitoring, Kestrel's real-time kinematic (RTK) GNSS data provides the accuracy needed to reliably monitor structures such as dams and bridges. For scientists studying earthquake detection and aftershock analysis, the support of CenterPoint® RTX™ corrections is specifically valuable as the Kestrel unit might be located in remote areas.

In addition to internet-delivered RTX corrections support, recently satellite-delivered (L-Band frequency) CenterPoint RTX corrections were added to Kestrel's capabilities. Satellite delivery ensures the flow of corrections data is not affected by communication delays or network outages as can be the case with internet-delivered RTX corrections. Communication outages can be caused by a technical issue or a natural disaster like an earthquake.

Key Considerations in Structural Monitoring

Safety: In most cases, the type of data required for monitoring is mostly the same for any structure - be it a building, a bridge or a dam, for example. Focusing on the monitoring of bridges and dams in this article, these structures can have additional hardware that monitor specific types of stress (such as crack gauges or piezometers for movement). These systems provide data on the integrity of the structure, from instant warnings, to detection and notifications of any change in the health of the structure. Such detections are critical, considering many dams and bridges are built to service large population centers, and are ageing structures with constant pressure or strain.

Installing additional monitoring systems to increase monitoring capabilities represents a commitment to the safety of the structure and those working or living around it. This is especially important when very large structures such as bridges and dams experience very subtle motion that would go undetected without a monitoring system. Even the slightest movement can lead to catastrophic failure.

Figure 1. The Trimble® Kestrel™ seismogeodetic system.

Figure 2. Visualization of the displacement and/or settling of the dam. In this case, for the crest of the dam..

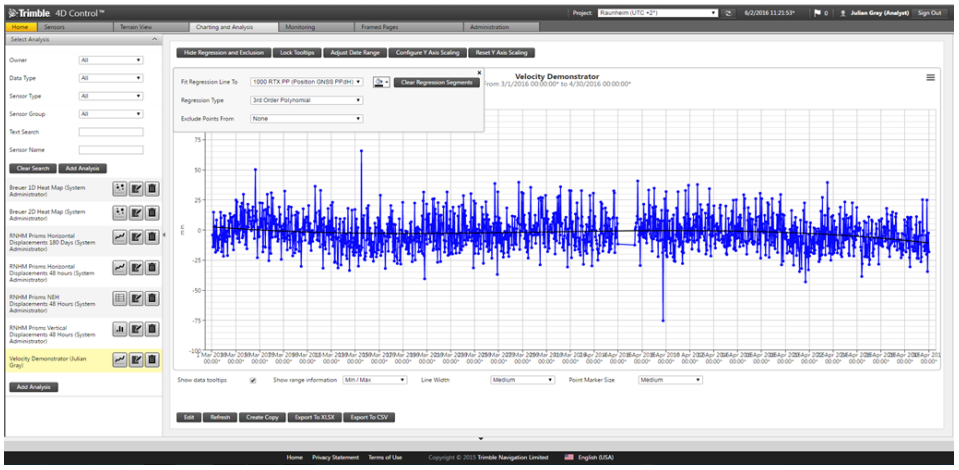

Figure 3. Visualization of time series acceleration data.

Simplified Setup and Installation: The Trimble Kestrel seismogeodetic system integrates a high-sample rate, strong motion accelerograph with Trimble's latest GNSS reference receiver technology in a single instrument, reducing the amount of equipment required to monitor a structure, and also reducing site installation time. With an IP67 rating, the compact and rugged Kestrel is ideal for deployment in extreme environments.

The seismic component, known as an accelerograph, that is built into Kestrel provides an advantage when monitoring bridges, towers or large dams with roadways. With this capability, Kestrel removes the need for additional monitoring equipment, specifically an accelerograph, which is able to record seismic (or any vibration) activity.

A Single Software Solution: When you have several instruments gathering complex data about a structure, it's important to have software that can deliver that data in a simple interface that visually provides a picture of what is happening in real-time.

Trimble's 4D Control monitoring software integrates position changes based on kinematic GNSS and acceleration data in X, Y, and Z directions both delivered by the Kestrel. The two independent data sets are combined and processed in a common, loosely coupled Kalman filter resulting in a high-frequency displacement dataset. For structural engineers and others studying the displacement of any structure, the Kalman filter data delivers higher sample rate displacement data, which is more precise than the traditional method of double-integrating the accelerometer data to derive the displacement data.

Trimble 4D Control offers comprehensive visualization, analysis and alerting tools for further data interpretation. Peak displacements are continuously monitored and if direction specific thresholds are exceeded, alarms are automatically issued to the user for informed decision making. Trimble 4D Control also allows to output the processing results for usage with third-party software.

Alerts: Over time, the operator will become familiar with the normal behavior of each monitoring point and will understand the typical, or expected, movement of the structure. When a motion goes beyond the expected, an alert based on the operator's criteria is sent, detailing the change in behavior. Real-time capabilities from Kestrel's satellite-based corrections can detect movement at any moment in time.

Monitoring Applications

Bridges: Bridges, by definition, are built over rivers, gorges or other bodies of water, which can result in

Figure 4. A portion of the King Fahd Causeway, connecting Saudi Arabia and Bahrain. The five dual, individual pillar supported bridges have Trimble Monitoring Solutions systems installed for real-time monitoring.

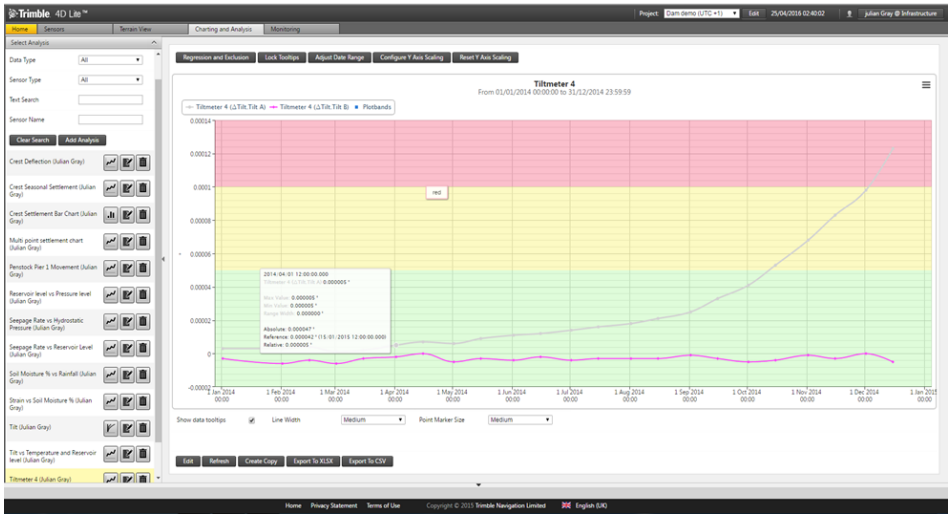

Figure 5. Tiltmeter visualization within Trimble 4D Control.

Figure 6. Trimble 4D Control's customizable view that allows users to import pictures of their specific structure for easier visualization.

weather variances and sometimes extreme heat or cold conditions requiring all instrumentation to be robust and weatherproof - which Kestrel provides.

Additionally, bridges built more than 20 years ago were not designed for the amount of traffic traveling across them today, making monitoring of the structure even more critical.

Typically, bridges that require monitoring tend to have a high volume of traffic, which makes equipment installation challenging. In most cases, traffic lanes need to be closed while post-construction installation takes place, therefore the instrumentation must be simple and quick to install and require little to low maintenance.

Dams: The specific needs for dam monitoring varies from those that are narrow and used solely as a dam to those that are wider and have a roadway with traffic regularly moving across them.

From subtle to seismic movements, damage to a dam must be measured with great care, monitoring the day-to-day status of the structure in order to provide a benchmark for change, similar to bridge monitoring. Monitoring the rate of change on the structure itself, leakage and pore water pressure over time can all provide an ongoing safety health check.

The specific monitoring system required for a dam will be determined by several factors including height and type, potential risk to people and structures within the flood zone, and site seismicity. In many countries, dam monitoring must adhere to strict standards. Preventative actions through early warning of degradation are commonly required when monitoring the structural health of a dam.

The Bottom Line: Continuous monitoring with Trimble's Kestrel seismogeodetic system lets structural engineers provide accurate, timely information for engineers and reliable monitoring system delivers accurate and reliable results, centralized control and exceptional cost efficiency.

Figure 7. A user control center, which enables users to easily view and visualize real-time data. This is the King Fahd Causeway control center.